Vertical Variation of Cloud Droplet Size Using Ship and Space-borne R/S Data

Contributors

Zhanqing Li, *University of Maryland*; Ruiyue Chen, *University of Maryland*; Robert Wood, *University of Washington*; Fu-Lung Chang, *National Institute of Aerospace*; Ralph Ferraro, *NOAA/NESDIS, WWBG*

Research Highlight

Low level stratiform liquid water clouds have a significant influence on the earth's climate due to their strong shortwave radiative forcing. Such clouds cover large regions of the earth's oceans [Klein and Hartmann 1993]. The shortwave optical depth of liquid water clouds depends upon both the bulk condensate amount and the size of the cloud drops. Dependence on the latter is expressed conveniently as an effective radius. The vertical variation of cloud droplet effective radius (re) is an important cloud property that reflects both condensation and coalescence growth. Satellite observation is the only practical means to infer cloud re globally. Solar reflectance measurements from a visible channel and a single near infrared (NIR) channel are used widely to estimate cloud optical depth and cloud top re. The retrieved values only represent a thin layer near cloud tops. Chang and Li [2002, 2003] proposed a method to determine an optimal linear re profile by using a combination of NIR measurements.

Using data from the EPIC 2001 Stratocumulus Study, this study investigates the cloud re vertical variation for drizzling and non-drizzling clouds. Estimates of the partitioning of liquid water content between drizzle drops and small cloud droplets is carried out using millimeter wave cloud radar (MMCR) data in drizzling stratocumulus by incorporating simultaneous liquid water path (LWP) estimates from a passive microwave radiometer. Satellite reflectance measurements from the moderate-resolution imaging spectroradiometer (MODIS) on the Terra satellite are used to estimate the trend of vertical re variation. Using drizzle rates estimated with a scanning C-band radar we show that the cloud re can decrease with height in clouds with sufficiently strong drizzle. For non-drizzling clouds, the re generally increases with height in accordance with the growth of cloud droplets by condensation. For drizzling clouds, at cloud base, liquid water content of drizzle drops is found to be of comparable magnitude to liquid water content of small cloud droplets when rain rate at cloud base is above a few hundredths of a mm hr-1. Both previous theoretical analyses and the synergetic observations in this study suggest that drizzle drops can increase re significantly at drizzle rates found in low liquid water clouds. Because drizzle is typically found towards the bottom of these clouds, the re increase by drizzle drops at cloud base can change the trend of vertical re variation and re can decrease with height if drizzle is heavy. Based on the radar precipitation observations and satellite cloud re profile estimation, re generally decreases with height when rain rate is above 0.1 mm hr-1.

Both re at cloud base and re at cloud top are shown to have certain distinction between drizzling and non-drizzling clouds: larger for drizzling clouds than for non-drizzling clouds. The distinction is more striking for re at cloud base than re at cloud top (see attached figures). The re at cloud base is also found to be better correlated with rain rate. The finding of this study suggests that

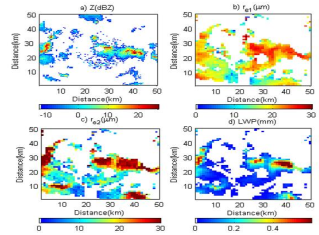

Figure 1. Coincident images of C-band radar reflectivity and MODIS cloud profile at UTC 15:55, Oct. 18, 2001. a) RHB C-band radar reflectivity image. b) MODIS estimation of droplet effective radius at cloud top (re1). c) MODIS estimation of droplet effective radius at cloud base (re2). d) MODIS LWP estimation.

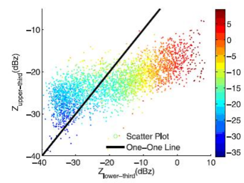

Figure 2. Scatter plot of reflectivities over upper 1/3 portion of cloud layer (Zupper-third) and reflectivities over lower 1/3 portion of cloud layer (Zlower-third) with data from MMCR. Color of the scatter plots represents the column maximum radar reflectivity.

the profile of re has the potential for drizzle detection in marine low clouds. Drizzle detection is very important in climate studies because drizzle can affect the optical properties of low clouds by changing their macrophysical and microphysical structure. It is important to develop methodologies for the detection and quantification of drizzle and other light precipitation in low clouds.

Reference(s)

Chen, R, R Wood, Z Li, R Ferraro, and F Chang. 2008. "Studying the vertical variation of cloud droplet effective radius using ship and space-borne remote sensing data." Journal of Geophysical Research 113, doi:10.1029/2007JD009596.

Working Group(s)

Cloud Properties